Interferometer Filter System for Precision Machine Tools

Displacement interferometers are used on many precision machine tools to measure and control machine motion. The interferometer electronics (IE) provide a digital feedback displacement signal directly to the machine-tool controller. Because the interferometer is a high-bandwidth system and the machine-tool controller has a relatively low sample rate, an alias signal can be downshifted into the control bandwidth of the motion controller and cause false machine motion.

As precision machines are approaching nanometer levels of displacement control, the alias of a high-frequency signal, such as a mirror-mount resonance, must be considered. There can be no mechanical resonance or noise measured by the interferometer that is greater than one half of the machine-tool controller sample rate. The interferometer electronics output signal is in digital form, and filtering at the controller sample rate can not remove the alias signal. The only way to properly handle the problem is to over-sample the interferometer output signal, and then process this signal with a digital filter to bandwidth limit it to less than half the controller sample rate.

Project Goals

The goal of this project is to use off-the-shelf IE and couple these electronics with a dedicated computer running a real-time operating system that will over-sample the IE and digitally filter the data. The results will then be presented to the machine controller in the proper data format and at the machine-controller sample rate (Fig. 1).

Our final products are the hardware and software needed to reach this goal.

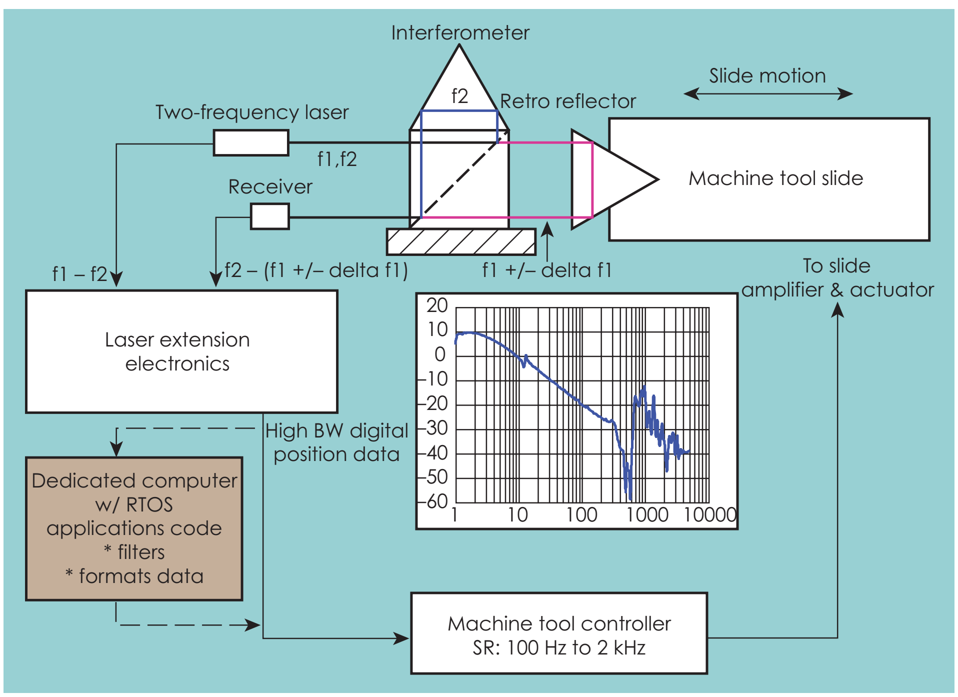

Figure 1. Concept diagram of the project. The laser extension electronics is the VME-based four-channel IE. The pink box represents the CPU that over-samples the IE and then filters and formats the data for the machine-tool controller.

PRECISION ENGINEERING

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Relevance to LLNL Mission

This project supports the LLNL precision manufacturing infrastructure. It will be used for new machine tools and allows a path to retrofit old machines.

FY2005 Accomplishments and Results

Displacement interferometry measurement is typically done by electronically interpolating the wavelength of a red laser light (633 nm). The highest resolution interpolation electronics (0.15 nm for a plane mirror interferometer) is commercially available only as a card based on the Versa Module Eurocard (VME) bus form factor (Fig. 2). In this project, a VME-bus-based embedded computer system was assembled to process the signal from an IE card. A real-time operating system is the software foundation of this system, since the measured and processed data must be delivered in a time-critical fashion to the machine controller.

Besides the assembly of the system, application code has been written in C++ to set up the hardware, read the interferometer card, create second-order bi-quad filters, and process the raw interferometer data through these filters. The function of the filters has been confirmed with simulated data. The number of second-order filters is selectable, as is the five-filter coefficients per filter.

A laser head and interferometer have been set up on a test machine (Fig. 3) so the interferometer can be moved to provide a signal for the VME interferometer card. The testing algorithm is to excite the moving slide through a range of frequencies and record the frequency spectrum before and after the filters of the system are activated. Figure 4 shows an example of expected results.

During software coding, a problem was found with hardware system interrupts. The interrupt is used to sync this system with the machine controller. Future work will address the interrupt problem and allow for final testing.

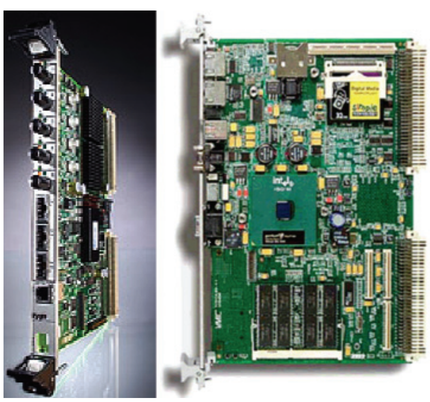

Figure 2. VME-bus-based cards, four-channel interferometer extension electronics, and CPU card.

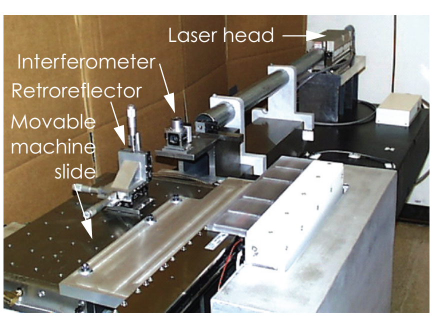

Figure 3. Interferometer test set-up.

Related References

1. Lam, H., Analog and Digital Filters Design and Realization, Prentice Hall, New Jersey, 1979.
2. Peterson, W., The VMEbus Handbook, VMEbus International Trade Association, 1989.

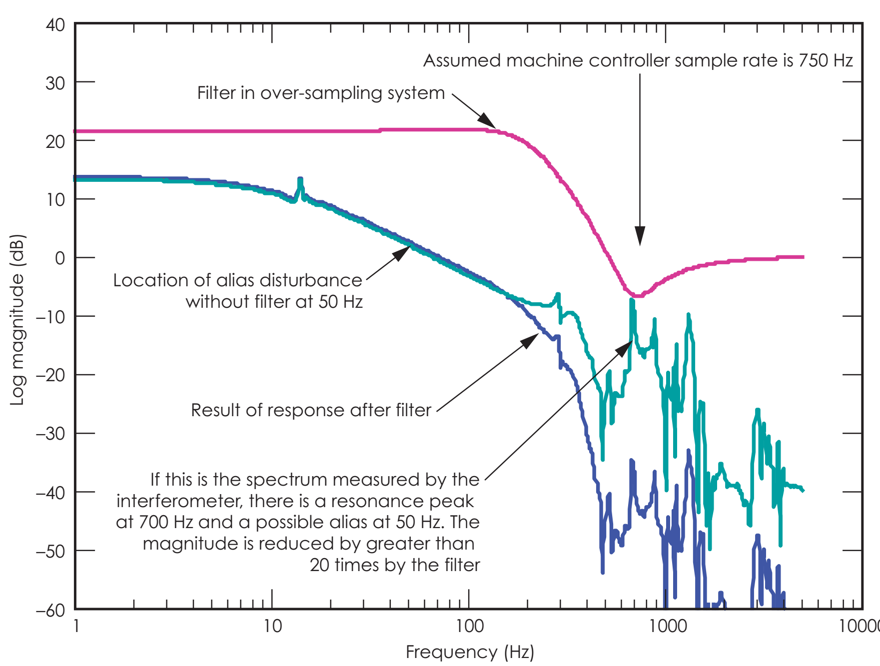

Figure 4. Example transfer function showing the possible alias issue with the project solution.